

PROJECT ADMINISTRATION DATA SHEET

☒

ORIGINAL

☐

REVISION NO. _____

Project No. A-3563

GTRI/GIT

DATE 6 / 13 / 83

Project Director: W. H. Spain

~~XXXX~~ Lab

EDL/SHD

Sponsor: Southern Fiber Control Technologies, Inc.

Type Agreement: P.O. No. 14293 dtd. 6/2/83

Award Period: From 6/1/83 To 7/30/83 (Performance) 7/30/83 (Reports)

Sponsor Amount:

This Change

Total to Date

Estimated: \$ _____ \$ 8,500

Funded: \$ _____ \$ 8,500

Cost Sharing Amount: \$ _____ Cost Sharing No: _____

Title: Air Sampling for Fiber Tek

ADMINISTRATIVE DATA

OCA Contact Faith G. Costello Ext. 4820

1) Sponsor Technical Contact:

2) Sponsor Admin/Contractual Matters:

Stan Shaw, President

Southern Fiber Control Technologies, Inc.

5891 New Peachtree Rd., Suite 116

Doraville, GA 30340

451-5530

Defense Priority Rating: _____ Military Security Classification: _____

(or) Company/Industrial Proprietary: _____

RESTRICTIONS

See Attached NA Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of \$500 or 125% of approved proposal budget category.

Equipment: Title vests with NA

COMMENTS:

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SPONSORED PROJECT TERMINATION/CLOSEOUT SHEETDate 11/2/83Project No. A-3563 School/Lab EDL/SHD
~~XXXX~~Includes Subproject No.(s) N/AProject Director(s) W.H. Spain GTRI/~~GIT~~Sponsor Southern Fiber Control Technologies, Inc.Title Air Sampling for Fiber TekEffective Completion Date: 9/30/83 (Performance) 9/30/83 (Reports)

Grant/Contract Closeout Actions Remaining:

- | | |
|--|---|
| <input type="checkbox"/> None | <input type="checkbox"/> Govt. Property Inventory & Related Certificate |
| <input checked="" type="checkbox"/> Final Invoice or Final Fiscal Report | <input type="checkbox"/> Classified Material Certificate |
| <input type="checkbox"/> Closing Documents | <input type="checkbox"/> Other _____ |
| <input type="checkbox"/> Final Report of Inventions | |

Continues Project No. N/AContinued by Project No. N/A

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AIR MONITORING
DURING
ASBESTOS ABATEMENT PROJECT
for
SOUTHERN FIBER CONTROL TECHNOLOGIES, INC.
"FIBERTEK"
Doraville, Georgia
at
VETERANS ADMINISTRATION MEDICAL CENTER
Decatur, Georgia

Project Number A-3563
Final Report

GEORGIA INSTITUTE OF TECHNOLOGY
Environmental Health and Safety Division
Engineering Experiment Station
Atlanta, Georgia 30332
October 1983

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AIR MONITORING

VETERANS ADMINISTRATION MEDICAL CENTER Decatur, Georgia

Project No. A-3563

INTRODUCTION

The Georgia Tech Research Institute was retained by Southern Fiber Control Technologies, Inc. (also known as FiberTek) of Marietta, Georgia to provide air monitoring and sample analysis during an asbestos abatement project involving two areas at the Veterans Administration Medical Center in Decatur, Georgia. Sampling was performed during the period from June 3 to July 11, 1983. All samples were analyzed and reported to a FiberTek representative on an ongoing basis. The following report further documents the sampling and analyses. The results of the air samples are included in Appendix A. Appendix B is a copy of the sampling and analytical method used as a guide for the samples collected during this project.

DESCRIPTION OF THE WORK AREA

This project involved two areas of asbestos abatement inside the Veterans Administration Medical Center at Decatur, Georgia. Each area involved approximately 1,000 square feet of floor space at the rear of the building. The downstairs area was on the ground level at the rear of the building; it involved four rooms and three hallways in the vicinity of Neurology and Plastic Surgery Research. The second area was up one level (upstairs) at the rear of the building; it included several rooms between the Operating Room and Radiation Therapy Halls.

AIR MONITORING PROCEDURES AND RESULTS

Air monitoring was conducted to assess airborne fiber concentrations in and around the two involved work areas. Air samples were collected during all phases of the work: preparation, abatement, clean-up, and after clean-up (clearance samples). The samples were collected with DuPont Model P-2500 and Model P-4000 pumps (constant flow) which had been calibrated with a bubble meter.

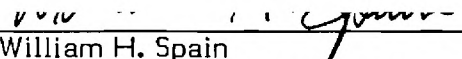
The air samples were collected and analyzed as described in the National Institute for Occupational Safety and Health (NIOSH) method P&CAM 239. It should be noted that while this is the currently accepted method of sampling and analysis, it does have some limitations.

First, the method does not distinguish between most fiber types; if collected on the filter, fibers other than asbestos will be included in the fiber count. Secondly, the method does not allow detection and counting of fibers (asbestos or others) which are shorter than 5 micrometers in length. Currently, the only method available to help overcome these limitations is analyses by electron microscopy. This

analytical technique would have increased the cost of performing air sampling and analysis ten-fold; it would also have required several weeks to obtain the results. This waiting period for results would have been unacceptable since a hazardous exposure condition could have existed for days or weeks undetected. The NIOSH method used was able to detect any gross contamination much more rapidly.

Approximately 135 air samples and 25 "blank" samples were collected during 25 days of this project between the dates of June 3 and July 11, 1983, inclusive. Those samples were submitted when collected on a daily basis to the Georgia Tech Environmental Laboratory. The Laboratory analyzed the samples and reported the fiber counts to one of the consultants who was collecting the samples. The consultants calculated the fiber concentrations and reported or presented them to a representative of FiberTek. Those same results are presented on the Industrial Hygiene Sampling Summary sheets in Appendix A of this report.

This Report Prepared By:



William H. Spain
Certified Industrial Hygienist

This Report Reviewed By:

Kenneth A. Smith, CIH
Head, Industrial Hygiene Branch

WHS:KAS:rm

APPENDIX A
Sample Summary and Results

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FIBERTEK

Materials DURING PREP. UPSTAIRS

FIBERTEK JOB # 0502G

Collected By: W. Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			FIBERS PER FILTER	FIBERS PER C.C.
6/3/83	AA 331	INSIDE DURING PREP HALL @ ROOM C107	940	1823	1046	523	46,200	0.04
6/3/83	AA 332	INSIDE DURING PREP ROOM C115	945	1824	1007	501	100,800	0.10
6/3/83	AA 333	INDOORS, OUTSIDE WORK AREA-NEAR BARRIER; OUTSIDE ROOM C138	957	1825	1029	512	11,200	0.01
6/3/83	AA 335	INDOORS, OUTSIDE WORK AREA-NEAR BARRIER; O R ENTR. @ B135	1007	1826	1003	499	11,200	0.01
6/3/83	AA 336	OUTDOORS;; HANGING DOWN OVER GREEN RAMP	1101	1835	913	454	5,600	< 0.01
6/3/83	AA 334	OUTDOORS; HANGING DOWN AT STEPS UNDER OVERHANG	1000	1051	103	*51	8,400	*0.08
6/3/83	AA 337	BLANK FILTER		1845			<2,800	

*GEN CONTRACTOR HAS BEEN/IS REMOVING CONCRETE BLOCK WALL FROM THIS AREA ON SECOND FLOOR; SHOVELLING UP, MOVING TO THE OUTSIDE AND THROWING FROM THE SECOND LEVEL BALCONY INTO AN OPEN TRUCK (VERY DUSTY). FILTER REMOVED AND *IN S.*

Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FIBERTEK
JOB # 0502G

Materials DOWNSTAIRS DURING PREP AND CEILING BREAK-
THROUGH

Collected By: W. Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			FIBERS PER FILTER	FIBERS PER C.C.
6/7/83	AA 342	INDOORS/OUTSIDE OF WORK AREA; NEAR NEURO. RES., ROOM B45	1512	1725	267	133	<2,800	<0.01
6/7/83	AA 348	INDOORS/OUTSIDE OF WORK AREA; NEAR GLASS WASHING, ROOM B13	1514	1727	267	133	<2,800	<0.01
6/7/83	AA 347	OUTDOORS; 20 FT DOWNWIND OF "HOG" EXHAUST	1520	1731	262	131	4,200	0.02
6/7/83	AA 352	INSIDE WORK AREA	1533	1615	84	42	*0 L	0 L
6/7/83	AA 476	INSIDE WORK AREA	1615	1645	60	30	0 L	0 L
6/7/83	AA 338	INSIDE WORK AREA	1535	1555	40	20	0 L	0 L
6/7/83	AA 478	INSIDE WORK AREA	1555	1608	26	13	0 L	0 L
6/7/83	AA 481	INSIDE WORK AREA	1608	1631	46	23	195,000	4.24
6/7/83	AA 344	INSIDE WORK AREA	1631	1701	60	30	144,000	2.40
6/7/83	AA 355	BLANK FILTER					<2,800	

* TOO MUCH DUST AND MATERIAL COLLECTED ON FILTER TO ALLOW FIBER COUNTING BY P&CAM TECHNIQUE

W. Spain

Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant Fibertek/VA
JOB # 0502G

Materials DuPont P-2500 Constant Flow Samplers
0.8 micron MCEF

Collected By: P. Middendorf, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers/cc	Total Fibers
6/8/83	AA-349	Outside: Rm B-27A	8:37	11:00	286	143	<0.01	< 2800
6/8/83	AA-472	Outside: Rm B-45	8:28	10:54	292	146	<0.01	< 2800
6/8/83	AA-350	Outside: Rm B-13	8:33	10:58	290	145	<0.01	< 2800
6/8/83	AA-345	Outside: Downstream from "Hog"	8:23	11:04	322	161	0.01	4200
6/8/83	AA-473	Inside: Rm B-46	9:16	10:16	120	60	2.75	330,000

Note: Room numbers refer to the room near where the outside samples were taken. Samples were taken on the outside of the barrier, in the hall.

Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Tearing out ceiling & wetting asbestos

Collected By: P. Middendorf, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/9/83	AA-477	Outside building: Downstream from "Hog"	8:09	12:09	480	240	12,600	0.03
6/9/83	AA-468	Outside work area: Hall near Room B-45	8:14	11:57	446	223	5,600	0.01
6/9/83	AA-346	Outside work area: Hall near Room B-27A	8:18	12:02	448	224	21,000	0.05
6/9/83	AA-486	Outside work area: Hall near Room B-13	8:19	12:05	452	226	8,400	0.02
6/9/83	AA-470	Blank					<2,800	

Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Downstairs inside work area during removal

Collected By: W. Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/9/83	P-9224 AA-485	Near center of room	1849	1905	32	16	1,070,000	33.4
6/9/83	P-9224 AA-475	Near center of room	1905	1917	24	12	229,600	9.6
6/9/83	P-9224 AA-146	Near center of room	1917	1942	50	25	417,970	8.4
6/9/83	P-9224 AA-467	Near center of room	1942	2001	38	19	707,000	18.6
6/9/83	P-9224 AA-308	Near center of room	2001	2011	20	10	920,000	46.0
6/9/83	P-9224 AA-386	Near center of room	2011	2021	20	10	448,437	22.4
6/9/83	P-9224 AA-466	Near center of room	2021	2037	32	16	1,020,000	31.9
6/9/83	P-9224 AA-479	Near center of room	2037	2052	30	15	848,484	28.3
6/9/83	P-9224 AA-324	Near center of room	2052	2100	16	8	431,110	26.9

Engineering Experiment Station
Safety & Health Services

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials	Asbestos Abatement Project
	Downstairs - outside work area during removal
Collected By:	H. Smith, GH

Collected By: W. Spain, CIH

[illegible]

Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center Materials Asbestos Abatement Project
Decatur, Georgia Downstairs - during removal
 Collected By: W. Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/10/83	P-9340 AA-313	Outdoors downstream from "Air Hog"	902	1446	687	342	5,600	<0.01
6/10/83	P-7119 AA-321	Indoors/outside work area near neuro & plastic sur. - Rm B-45	917	1437	643	320	16,000	0.02
6/10/83	P-7710 AA-325	Indoors/outside work area across from glass washing B-13	923	1440	637	317	42,000	0.07
6/10/83	P-7719 AA-320	Indoors/outside work area near derm. res. & Rm B-26	924	1441	637	317	<2,800	<0.01
6/10/83	P-7049 AA-316	Near baggers inside work area	1107	1122	31	15	950,00	30.6
6/10/83	P-7049 AA-319	Near baggers inside work area	1122	1152	62	30	1,020,000	16.5
6/10/83	P-N/A AA-306	Blank		1220			25,000	
6/10/83	P-9224 AA-323	Center of room inside work area	1107	1137	60	30	74,000	1.2
6/10/83	P-9224 AA-307	Tunnel @ corner	1137	1209	64	32	250,000	3.9

Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Basement level during removal

Collected By: Ken Smith, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/11/83	P-7719 AA-356	Indoors/outside work area - near derm. res. & Rm B-26 & B-27	8:54 AM	12:56 PM	484	242	<2,800	<0.01
6/11/83	P-7049 AA-362	Indoors/outside work area - near neurosurgical res. Rm B-45	8:48 AM	12:48 PM	480	240	<2,800	<0.01
6/11/83	P-7710 AA-371	Indoors/outside work area - near glass washing - Rm B-13	8:50 AM	12:53 PM	486	243	<2,800	<0.01
6/11/83	P-9333 AA-372	Outdoor - downstream from Air Hog	9:03 AM	1:05 PM	484	242	8,400	0.02
6/11/83	P-9340 AA-367	Bagging area - near bag removal	9:30 AM	10:00 AM	60	30	500,000	8.3
6/11/83	P-7119 AA-363	working area - center of room where scrapping occurs	9:28 AM	9:43 AM	30	15	670,000	22.3
6/11/83	AA-357	Blank					<2,800	

Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
During removal

Collected By: K. Smith, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/12/83	P-7049 AA-380	Indoors/outside work area near neuro-surg. res. Rm B-45	8:54	12:54	480	240	<2,800	<0.01
6/12/83	P-7119 AA-378	Indoors/outside work area near glass washing Rm B-13	8:57	12:58	482	241	<2,800	<0.01
6/12/83	P-7719 AA-377	Indoors/outside work area near derm. res. Rm B-26, B-27	8:59	1:01	486	243	2,800	<0.01
6/12/83	P-7710 AA-358	Outdoors - downstream from Air Hog	9:05	1:10	490	245	5,600	0.01
6/12/83	P-9340 AA-366	Room where scrapping is being done	9:47	10:02	30	15	1,570,000	52.3
6/12/83	P-9333 AA-361	Bagging	9:26	9:56	60	30	840,000	14.0
6/12/83	AA-373	Blank					2,800	

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project

Collected By: K. Smith, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/13/83	AA-413	Outdoors, downwind from hog	9:28	12:10	324	162	0.02	5,600
6/13/83	AA-404	Dermatology res., near B-27 & 26	9:41	12:16	310	155	0.07	22,400
6/13/83	AA-410	Adjacent B-48A	9:47	12:13	292	146	<0.01	<2,800
6/13/83	AA-416	Glass washing area, near B-19	9:43	12:16	306	153	0.03	8,400
6/13/83	AA-403	Neuro & plastic surg. res. B-45	9:35	12:13	316	158	0.01	<2,800
6/13/83	AA-415	Room B-10 - Lab	9:45	12:17	304	152	0.02	5,600
6/13/83		Blank						<2,800

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Downstairs - wire brushing

Collected By: P. Williams, CIH & K. Kamperman

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/14/83	P-9224 AA-317	Downwind outside Hog	10:08	12:27	279	139	<0.01	<2,800
6/14/83	P-7710 AA-311	B-48	10:11	12:18	255	127	<0.01	<2,800
6/14/83	P-9333 AA-315	Neuro and plastic surgery	10:13	12:19	253	126	<0.01	<2,800
6/14/83	P-9340 AA-484	Glass washing	10:15	12:21	253	126	0.03	8,400
6/14/83	P-7719 AA-488	Dermatology research	10:17	12:21	249	124	0.03	8,400
6/14/83	P-7049 AA-480	Inside room after brushing before wiping	10:49	11:09	40	20	32.2	1,300,000
6/14/83	AA-314	Blank						<2,800

Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Asbestos removal

Collected By: K. Kamperman/K. Smith, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/15/83	P-9224 AA-407	Outside air lock near B-48 perimeter samples	10:18	2:28	500	250	2,800	<0.01
6/15/83	P-7119 AA-418	Perimeter sample near B-13 glass washing room	10:23	2:31	496	248	<2,800	<0.01
6/15/83	P-9333 AA-417	Perimeter sample - derm. res. area - near B-26	10:25	2:34	498	249	12,060	0.02
6/15/83	P-7049 AA-423	Outside air sample - loading dock - downstream from Air Hog	10:35	2:36	482	241	2,800	<0.01
6/15/83	P-7716 AA-487	Inside work area - inside Histo. Lab	11:05	11:37	64	32	980,000	15.31
6/15/83	P-9340 AA-401	Inside work area - hallway upstream from Air Hog	11:00	11:32	64	32	370,000	5.78
6/15/83	AA-383	Blank					4,200	

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek-at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Asbestos removal

Collected By: K. Kamperman

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/16/83	P-9340 AA-411	Outside air sample - loading dock downstream from Air Hog	12:57	4:10	386	193	2,800	0.01
6/16/83	P-7716 AA-402	Perimeter sample - outside room B-45 - neurological research	1:07	4:14	374	187	2,800	0.01
6/16/83	P-7727 AA-424	Perimeter sample - outside room B-26 - dermatological res.	1:15	4:24	378	189	2,800	0.01
6/16/83	P-7709 AA-310	Perimeter sample - outside room B-26 - dermatological research	1:18	4:26	376	188	2,800	0.01
6/16/83	P-7710 AA-405	Containment sample - inside room B-48 - storeroom (clean air)	1:32	4:33	362	181	23,000	0.06
6/16/83	AA-420	Blank					2,800	

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Asbestos removal

Collected By: K. Kamperman

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/17/83	P-7049 AA-368	Outside air sample - loading dock downstream from Air Hog	2:33	6:33	480	240	<2,800	<0.01
6/17/83	P-9340 AA-414	Perimeter sample - outside room B-45 - neurological research	2:44	6:44	480	240	<2,800	<0.01
6/17/83	P-7716 AA-374	Perimeter sample - outside room B-13 - Glass washing	2:40	6:40	480	240	<2,800	<0.01
6/17/83	P-7727 AA-412	Perimeter sample - outside room B-26 - dermatological research	2:41	6:41	480	240	<2,800	<0.01
6/17/83	P-7709 AA-419	Containment sample - inside room B-48 - storeroom after clean	3:04	7:04	480	240	19,000	0.04
6/17/83	P-7710 AA-365	Containment sample - inside Histopahtology rm. during clean	3:12	7:14	484	242	840,000	1.74
6/17/83	AA-369	Blank					<2,800	

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center Materials Asbestos Abatement Project
Decatur, Georgia Asbestos removal

Collected By: Kevin Kamperman

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/18/83	P-7710 AA-376	Outside air sample - loading dock downstream from Air Hog	12:01	4:01	480	240	<2,800	<0.01
6/18/83	P-7727 AA-370	Perimeter sample - outside room B-45 - neuro. research	12:10	4:11	482	241	<2,800	<0.01
6/18/83	P-9340 AA-359	Perimeter sample - outside room B-13 - glass washing	12:13	4:14	482	241	<2,800	<0.01
6/18/83	P-7709 AA-360	Perimeter sample - outside room B-26 - dermatological research	12:14	4:15	482	241	<2,800	<0.01
6/18/83	P-7049 AA-425	Containment sample - inside room B-48 storeroom after clean	12:29	5:08	558	279	17,000	0.03
6/18/83	P-7716 AA-364	Containment sample - inside histopathology rm. during clean	12:34	5:15	562	281	225,000	0.45
6/18/83	AA-409	Blank					<2,800	

Engineering Experiment Station
Safety & Health Services

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project

Asbestos removal

Collected By: K. Kamperman

[illegible]

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Downstairs - removing hoses & equip.
upstairs - prepping
Collected By: W. Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/20/83	P-9340 AA-421	Outdoors (upstairs) 20 ft. downwind Hog exhaust	1002	1316	388	194	<2,800	<0.01
6/20/83	P-7709 AA-375	Outside barrier - Rad. Therapy hall near C-138 (upstairs)	1006	1308	364	182	<2,800	<0.01
6/20/83	P-7710 AA-379	OR hall outside barrier near room B-155 (upstairs)	1018	1307	338	169	<2,800	<0.01
6/20/83	P-7727 AA-514	Inside upstairs area "cross hall" - during light prep	1150	1254	128	64	<2,800	<0.1
6/20/83	P-7049 AA-510	Outside barrier downstairs glass washing B-13	1026	1311	330	165	<2,800	<0.01
6/20/83	P-9333 AA-504	Outside barrier downstairs neuro & plastic sur. res. B-45	1034	1313	318	159	3,000	<0.01
6/20/83	AA-406	Blank					<2,800	

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Upstairs - finishing prepping
Downstairs - bond sealing
Collected By: W. Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/21/83	P-9340 AA-499	Outdoors - downwind of upstairs "Air Hog"	1503	1735	304	152	<2,800	<0.01
6/21/83	P-7710 AA-196	Upstairs outside barrier - OR hall @ room B-155	1510	1731	282	141	<2,800	<0.01
6/21/83	P-7049 AA-195	Upstairs outside barrier - Rad. therapy hall @ room C-138	1508	1733	290	145	<2,800	<0.01
6/21/83	P-7716 AA-197	Inside storeroom next door to B-48A	1541	2306	890	445	<2,800	<0.01
6/21/83	P-7709 AA-198	Inside back corner room downstairs 1 3/4 hrs. after bondseal	1551	2310	878	439	110,000	0.13
6/21/83	AA-201	Blank		1737			<2,800	

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center Materials Asbestos Abatement Project
Decatur, Georgia Upstairs - demo. (ceiling knock out)

Collected By: William Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/23/83	P-7709 AA-204	Outdoors - under overhang downwind of Air Hog exhaust	1329	1701	224	212	<2,800	<0.01
6/23/83	P-7727 AA-202	Outside barrier upstairs - Rad. therapy hall @ room C-138	1344	1659	390	195	<2,800	<0.01
6/23/83	P-7710 AA-207	Outside barrier upstairs OR hall @ B-155	1346	1657	382	191	<2,800	<0.01
6/23/83	P-7049 AA-214	Within 3 ft. of face during last minutes of ceiling knock out	1627	1633	12	6	100,000	8.3
6/23/83	AA-212	Blank		1650	Blank		<2,800	
6/23/83	P-9333 AA-209	Center of room immediately after ceiling knock out	1633	1643	20	10	98,000	4.9

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Asbestos removal

Collected By: W. Spain, CIH & K. Kamperman

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/24/83	P-7727 AA-211	Outside air sample - downwind from upstairs hos - on steps	8:44	1:21	554	277	4,000	<0.01
6/24/83	P-7709 AA-215	Perimeter sample - upstairs - Rad. therapy hall - rm. C-138	8:46	1:20	552	276	<2,800	<0.01
6/24/83	P-7710 AA-213	Perimeter sample - upstairs - OR hall room B-155	8:47	1:19	552	276	3,000	<0.01
6/24/83	AA-219	Blank					<2,800	

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Asbestos removal

Collected By: K. Kamperman

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/25/83	P-7727 AA-250	Outside air sample - downwind from upstairs hog - on steps	9:30	1:34	488	244	<2,800	<0.01
6/25/83	P-7709 AA-245	Perimeter sample - upstairs Rad. therapy hall - rm. C-138	9:33	1:35	484	242	<2,800	<0.01
6/25/83	P-7710 AA-267	Perimeter sample - upstairs - OR hall - rm. B-155	9:34	1:38	488	244	<2,800	<0.01
6/25/83	AA-273	Blank					<2,800	

Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Downstairs - clearance

Collected By: W. Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/26/83	P-7716 AA-199	Outdoors downwind of Air Hog	1030	1307	314	157	<2,800	<0.01*
6/26/83	P-9224 AA-218	Upstairs outside barrier - Rad. therapy hall @ rm. C-138	1035	1159	168	84	<2,800	<0.02*
6/26/83	P-9333 AA-216	Upstairs outside barrier - OR hall @ room B-155	1047	1157	140	70	<2,800	<0.02*
6/26/83	AA-247	Blank		1350	Blank		<2,800	
6/26/83	P-9224 AA-208	Clearance sample - downstairs inside room from back door	1232	1900	776	388	210,000	0.27
6/26/83	P-9333 AA-217	Clearance sample - inside room nearest back door - downstairs	1247	1901	748	374	Voided/Contaminated	
6/26/83	AA-248	Blank		1917	Blank		<2,800	

*Below detection limit

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Demo Upstairs

Collected By: W. Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/29/83	P-7169 AA-697	Indoors outside barrier - upstairs Rad. therapy hall @ rm. C-138	752	1243	576	291	< 2,800	< 0.01
6/29/83	P-7702 AA-698	Indoors outside barrier - upstairs OR hall @ rm. B-155	754	1242	570	288	< 2,800	< 0.01
		No blank by co. request						

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Safety & Health Services
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project
Upstairs - clean up and final prep

Collected By: W. Spain, CIH

Date	Sample Number	Description	Sampling Period		Sample Volume (Liters)	Sample Time (Min.)	Concentration	
			Start	Stop			Fibers Per Filter	Fibers Per cc of Air
6/30/83	P-7672 AA-754	Clearance sample downstairs - inside room nearest back door	1254	1916	779	382	<2,800	<0.01
6/30/83	P-7103 AA-792	Clearance sample downstairs - inside room farthest fr. back dr.	1300	1917	762	377	5,100	<0.01
6/30/83	P-7169 AA-745	Indoors outside barrier Rad. therapy hall @ rm. C-138	1330	1933	719	363	<2,800	<0.01
6/30/83	P-7702 AA-766	Indoors outside barrier OR hall @ rm. B-155	1332	1932	713	360	7,000	<0.01
6/30/83	AA-741	Blank			Blank		<2,800	

Engineering Experiment Station
Safety & Health Services

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials Asbestos Abatement Project

Asbestos sampling

Collected By: P. Middendorf, CIH

[illegible]

*Some work going on near barrier and hog - may have been partially responsible

Georgia Institute of Technology
Engineering Experiment Station
Safety & Health Services

Plant FiberTek at VA Medical Center
Decatur, Georgia

Materials	Asbestos Abatement Project
	Asbestos removal -
	Suspected barrier leak on OR side

Collected By: K. Smith, CIH

[illegible]

APPENDIX B
Asbestos Fibers In Air
(NIOSH P&CAM 239 Technique)

ASBESTOS FIBERS IN AIR
National Institute for Occupational Safety and Health
Analytical Method

Analyte:	Asbestos fibers	Method No.:	P&CAM 239
Matrix:	Air	Range:	0.1-60 fibers/cm ³
Procedure:	Filter collection, microscopic count	Precision (CV_T):	0.24 to 0.38
Date Issued:	3/30/77	Classification:	D (Operational)
Date Revised:			

1. Principle of the Method

- 1.1 This method describes the equipment and procedures for collecting, mounting, and counting asbestos fibers on cellulose ester membrane filters in the evaluation of personal samples of airborne asbestos fibers. The purpose of the method is to determine an employee's index of exposure to airborne asbestos fibers. The method is primarily a personal monitoring technique, but can be used for area monitoring.
- 1.2 The sample is collected by drawing air through a membrane filter by means of a battery powered personal sampling pump. The filter is transformed from an opaque solid membrane to a transparent optically homogeneous gel. The fibers are sized and counted using a phase-contrast microscope at 400-450X magnification.
- 1.3 Definitions. Asbestos fiber, for counting purposes, means a particulate which has a physical dimension longer than 5 micrometers and with a length to diameter ratio of 3 to 1 or greater. Asbestos includes chrysotile, cummingtonite-grunerite (amosite), crocidolite, fibrous tremolite, fibrous anthophyllite, and fibrous actinolite.
- 1.4 Any laboratory attempting to use this procedure should have at least one counter attend a training course conducted by an experienced, proficient laboratory. Novice, untutored counters, using only published instructions, can easily obtain counts of half those performed by experienced, proficient counters. Large differences between laboratories can be caused by: 1) differences in technique and observing ability among counters and 2) small, but significant, differences between microscopes meeting the basic specifications of Section 6.2. The following procedures are recommended:
 - 1.4.1 All microscopists who perform asbestos counting should meet together for an "asbestos counting workshop" at least quarterly. This is best accomplished with counters from several laboratories using their own microscopes.
 - 1.4.2 Each microscopist should count the same series of slides and with the results being compared.
 - 1.4.3 Differences between counters should be resolved with side-by-side counting of the fields by the different counters.
 - 1.4.4 Individuals who are found to be persistent outliers over several sessions should be encouraged to seek other tasks in their respective laboratories.

2. Range and Sensitivity

2.1 The usable range is primarily a function of sample volume, microscope count field area, and background airborne particulates. The influence of these variables is discussed in 8.1.3. For a microscope count field area of 0.003 mm^2 (see Figure 1) and a pump flow rate of 1.7 lpm, the optimal fiber densities would be produced over the range of 0.4 fiber/cm³ (8-hour sample) to about 60 fibers/cm³ (15-minute sample). For a field area of 0.006 mm^2 (see Figure 2) and a pump flow rate of 1.7 lpm, the optimal range is 0.2 fiber/cm³ (8-hour sample) to about 30 fibers/cm³ (15-minute sample). In each case, the optimal detection limits are inversely proportional to pump flow rate.

The upper detection limit can be extended by using sample times less than 15 minutes or using lower flow rates. The lower detection limit can be extended by increasing the flow rate up to about 2.5 lpm. Filter surface fiber densities less than optimal (less than about 0.5 to 1.0 fiber per count field) are still adequate, but will lead to decreased precision for the method (increased coefficient of variation, see Section 4).

The minimum total fiber count in 100 fields considered adequate for reliable quantitation is 10 fibers. Thus, the lower limit of reliable quantitation is 0.1 fiber/cm³ (100,000 fibers/m³). For this level, a flow rate of about 2.5 lpm is recommended. For a field area of 0.003 mm^2 , the minimum sample time would be about 2 hours. For a field area of 0.006 mm^2 , the minimum sample time would be about 1 hour.

2.2 This method considers only fibers with a length to diameter ratio of 3 to 1 or greater and a length greater than 5 micrometers.

3. Interferences

In an atmosphere known to contain asbestos, all particulates with a length to diameter ratio of 3 to 1 or greater, and a length greater than 5 micrometers should, in the absence of other information, be considered to be asbestos fibers and counted as such.

4. Precision and Accuracy

4.1 In the past decade, there have appeared a number of articles examining sources of variation in the asbestos sampling and counting procedure. These include: Lynch et al. (11.1), Weidner and Ayer (11.2), Conway and Holland (11.3), Leidel and Busch (11.4), Beckett and Attfield (11.5), and Rajhans and Bragg (11.6). The sources of variation will be discussed by stages in the membrane filter evaluation procedure.

4.2 Sources of Variation in the Sampling Process. These include variations in pump flow rate, proximity of the filter to the employee's body, and filter location (left to right) in the employee's breathing zone.

4.2.1 Section 9.1 requires that the personal sampling pump be calibrated with sufficient accuracy such that the 95% confidence limits on the flow rate are $\pm 10\%$. This is equivalent to a coefficient of variation (CV) of about 5%. However, this CV makes a negligible contribution to the total CV for the method due to the relatively large CV of the counting procedure.

4.2.2 Conway and Holland (11.3) concluded that positioning of the filter cassette on the wearer (regarding the angular portions of the filter and their proximity to the wearer) is not a significant factor in determining the fiber distribution on filters.

4.2.3 Weidner and Ayer (11.2) concluded that there is no appreciable difference between samples collected on either the right or left sides of a breathing zone or between samples collected side-by-side, especially for samples with concentrations less than 2.5 fibers/cm³.

4.3 Sources of Variation in the Counting Procedure

4.3.1 Random variations exist in the fiber distribution on a filter wedge (intra-wedge variability). The industrial hygiene literature has seen considerable debate in the last 20 years concerning whether or not the distribution of mineral dust or asbestos fibers on a filter surface is adequately described by a Poisson distribution probability density function. Leidel and Busch (11.4) found excellent agreement between empirical error variance and theoretical variance calculated from the assumption of Poisson distributed true counts. They concluded that there was not excessive variation among count fields for a filter wedge and that clumping of fibers (non-random coalescence) did not occur.

4.3.2 Variations exist in the fiber distribution on the total filter surface (inter-wedge variability) due to the random or non-random distribution of fibers across the total surface of the filter. This type of variation is easily confused with intra-wedge variations. The count procedure does not require counting of multiple sectors of the filter. There may be significant differences between average counts for different wedges, or the filter distribution variations for the total filter surface may be greater than the variations of the Poisson distribution. If either of these occur experimentally, one must use the experimental variations to estimate the minimum precision of the count procedure. The minimum precision is governed by the variations of the fiber distribution on the total surface of the filter.

Conway and Holland (11.3) concluded the distribution of fibers on filters is not uniform and the distribution of fiber counts is more disperse than Poisson. For their filters which had significant variations in fiber concentrations between sectors (as much as 50-60% of the total filter mean), they described the following relation for the standard deviation of the total number of fibers counted on a wedge (N)

$$\text{empirical } s(N) = 1.6 (N)^{1/2}$$

where N is about 100. The Poisson standard deviation would be:

$$\text{Poisson } \sigma (N) = (N)^{1/2}$$

Rajhans and Bragg (11.6) in Series I of their study found significant variation between filter segments and rejected the Poisson distribution for the total filter surface. However, in Series II of their study, utilizing various experimental modifications, they found no significant variation between filter segments and no reason to reject the assumption of Poisson distributed fiber counts.

4.3.3 Systematic variations due to differences between microscopes were studied by Leidel and Busch (11.4). In their study using five different brands of microscopes, they found no significant differences among four, but the fifth gave counts approximately 45% higher on the average than the other four.

4.3.4 Variations due to differences between counters should be examined at three levels: experienced counters occasionally counting, experienced counters routinely counting, and inexperienced (new or untutored) counters. Leidel and Busch (11.4) studied five experienced counters, with one counting only occasionally. There were no significant differences among three of the counters, but a fourth was 16% lower than the first three. The fifth, who occasionally counted, averaged 27% higher than the first three. Conway and Holland (11.3) studied three experienced counters and three inexperienced counters. They found statistically significant differences between the means of both the experienced and inexperienced counters that typically were in the range plus or minus 5 to 15%. They concluded that experience as a fiber counter is not a significant parameter affecting intercounter variations.

Rajhans and Bragg (11.6) found no significant differences among means of five experienced counters in Series I of their study. But in their carefully controlled Series II, an analysis of variance showed significant variations between counters that were plus or minus 1 to 15%.

- 4.3.5 Variations between laboratories are most likely due to systematic biases and are not a significant additional source of random variations. Any additional variations are most likely due to differences in counting technique. Beckett and Attfield (11.5) observed that standard counters improved greatly after personal instruction; also new counters, after instruction, tended to overcompensate and get exceedingly high counts. Additionally, they found that counts from an experienced laboratory that had not had contact with other laboratories performing the same analysis were as far from the standard values as were the counts by new counters.
- 4.4 Sources of variations between samples taken at different times on one employee during one work shift can affect the exposure estimate for that employee. These are primarily due to a) differences in exposure concentrations during the day, b) differences in location of the employee within the plant, and c) differences in work operation performed by the employee during the day. These sources of variation can be controlled by proper choice of sampling strategy. Refer to Leidel and Busch (11.7) and Leidel, Busch, and Lynch (11.8) for an extended discussion of sampling strategies. Interday temporal variations can affect the exposure estimates obtained on different days. Refer to Leidel, Busch, and Crouse (11.9) for a discussion of this type of variation.
- 4.5 Until recently, the total coefficient of variation (CV_T) for the sampling and counting procedure was best estimated from the work of Conway and Holland (11.3). The conclusions of their study included:
- 4.5.1 The precision of their procedure for filters not containing an abundance of fine fibers can be estimated by a coefficient of variation of 16.2%. This value includes variation among counters and observed interaction effects.
- 4.5.2 The accuracy of the procedure for similar filters may be estimated for a 100-fiber count by a coefficient of variation of 21.4%. This assumes that the contribution of the overall variance from the nonuniform fiber distribution is additive.
- 4.5.3 A high percentage of very fine fibers on the filter can significantly affect the standard deviation and confidence limits for counts by different counters. After combining variations in fiber concentrations over the entire filter with those for different counters, it was concluded:
- For filters with a low concentration of fine fibers, the coefficient of variation is estimated at 21% and the 95% confidence interval is $\pm 43\%$.
 - For filters with a high concentration of fine fibers, the coefficient of variation is estimated at 25% and the 95% confidence interval is $\pm 50\%$.

Lynch, Kronoveter, and Leidel (11.1) have also reported on variations of the method. Their intralaboratory study utilized the data from a large number of dust counts made by different methods by experienced counters over a period of years in an epidemiologic study of the asbestos products industry. They concluded that the standard deviation of counts of fibers longer than 5 micrometers on membrane filters could be estimated from the relation $\sigma = (N)^{0.391}$. Thus for counts of about 100 fibers, the coefficient of variation could be estimated at about 15.2% and the 95% confidence limits at $\pm 30.4\%$. These values are lower than the values reported by Conway and Holland (11.3).

Recently, the Johns-Manville Corporation conducted an in-house investigation of the asbestos count method (11.10). The study data contained total fiber counts for over

100 filters with each filter counted by two to five counters. From the Johns-Manville data, NIOSH calculated over 100 estimates of the count CV for the method (11.10). The NIOSH CV estimates included random intrafilter variations and interfilter variations, but did not include random pump flow rate variations. It was found that the count coefficient of variation (all random variations except for pump variations) was a function of the total fiber count. NIOSH then included a CV of 0.05 for random pump variations (see Section 9.1) in the CV-estimator equation to obtain a CV_T -estimator. The CV_T -estimator line is plotted on Figure 3 for total fiber counts in the range 10 to 100 fibers. Or the following equation can be used:

$$CV_T = [\text{antilog}_{10}(-0.215 - 0.203(\log_{10}FB)) + 0.0025]^2$$

where FB is total fiber count as discussed in Section 10.

Figure 3 demonstrates that for a total fiber count of 100, the best CV_T is attainable with the appropriate sampling times given in 8.1.3 and the count rules in 8.3.9. When making decisions regarding compliance with the OSHA asbestos exposure standards in 29 CFR 1910.1001, the statistical procedures given in Leidel et al. (11.11) should be followed. The procedures are based on statistical theory and assumptions given in References 11.12, 11.13.

Because of the possibility of systematic biases due to differences between microscopes, counters, and laboratories as discussed above, it is strongly recommended that any laboratory counting asbestos should participate in an interlaboratory quality control program that includes the counting of standard reference filters. These standard filters are available from NIOSH through the Proficiency Analytical Testing (PAT) Program. The PAT Program is used by the American Industrial Hygiene Association (AIHA) as part of its Laboratory Accreditation Program. Each laboratory's quality control program must include protocols for routinely adjusting and calibrating sampling and counting equipment plus training and evaluation programs for counters.

5. Advantages and Disadvantages of the Method

- 5.1 The method is intended to give an index of employee exposure to airborne asbestos fibers of specified dimensional characteristics.
- 5.2 It is not meant to count all asbestos fibers in all size ranges or to differentiate asbestos from other fibrous particulates.

6. Apparatus

6.1 Sampling Equipment

The personal sampling equipment train consists of 1) personal sampling pump, 2) tubing, 3) clothing spring clip, 4) tubing-to-field monitor metal adaptor, and 5) field monitor (filter and holder).

- 6.1.1 Personal Sampling Pump. The pump must be capable of sampling at 1.0 to 2.5 liters per minute (lpm) against a flow resistance of 7.5 inches of water (1.4 cm Hg) for 8 continuous hours on a fully charged battery.
- 6.1.2 Tubing. Laboratory tubing such as rubber or plastic with 6-mm bore and about 100 cm length.
- 6.1.3 Clothing Spring Clip. The clip attaches the rubber tubing to the lapel or shirt of the individual being monitored.
- 6.1.4 Tubing-to-field Monitor Adaptor. A short metal adaptor with ridges on one end to grip the inside of the tubing. The other end is designed for a pressure fit into the field monitor.
- 6.1.5 Field Monitor (Filter and Holder). The only field monitor currently considered acceptable by NIOSH is manufactured by the Millipore Corporation. The unit con-

sists of 1) a three section styrene plastic case designated Millipore Aerosol Monitor Case, 2) a 37-mm diameter plain white cellulose ester membrane filter designated Millipore AA (pore size of 0.8 micrometer), 3) a support pad, and 4) two plastic sealing caps. If a large number of samples are to be taken, it may be less expensive to reuse the plastic cases. Great care must be taken in the cleaning and reassembly process. The outside mating surfaces of the field monitors may be covered with a "shrink-fit" band to provide proper sealing and a writing surface for filter identification.

6.2 Optical Equipment and Microscope Features

- 6.2.1 Microscope body with binocular head.
- 6.2.2 10X Huygenian eyepieces are recommended. Other eyepieces can be substituted if necessary. Wide field eyepieces can be used; however, wide field eyepieces may yield a count field area less than 0.003 mm² with the Porton reticle. This is not always desirable from the standpoint of obtaining optimum sampling times (see Section 8.1.3). If wide field eyepieces are used, it is preferable to use the Patterson Globe and Circle reticle to obtain a larger count field area.
- 6.2.3 Koehler illumination (preferably built-in with provisions for adjusting light intensity).
- 6.2.4 A Porton reticle is recommended. Others such as the Patterson Globe and Circle can be substituted.
- 6.2.5 Mechanical stage.
- 6.2.6 Phase-Contrast condenser with a numerical aperture (N.A.) equal to or greater than the N.A. of the objective.
- 6.2.7 40-45X phase contrast achromatic objective (N.A. 0.65 to 0.75).
- 6.2.8 Phase-ring centering telescope or Bertrand lens.
- 6.2.9 Green or blue filter, if recommended by microscope manufacturer.
- 6.2.10 Stage micrometer with 0.01 mm subdivisions.
- 6.2.11 For general guidance on phase contrast microscopy, consult Needham (11.12), Clark (11.15) and McCrone (11.14).

6.3 Filter Mounting Equipment. Experience has shown that certain equipment is useful for efficient sample mounting. The following items are recommended for extracting and mounting a portion of the filter for counting.

- 6.3.1 Microscope slides. 2.5 by 7.5 cm glass slides are most commonly used. Sample number, data, initials, etc., can be conveniently written on a frosted end slide.
- 6.3.2 Cover Slips. Cover slips are a necessary part of the slide mount and optical system. The shape should be appropriate for the size of the filter wedge. The appropriate cover slip depends upon the objective to be used. Ordinarily, objectives are optically corrected for a #1½ (0.17 millimeter) thickness cover slip. Improper cover glass thickness will detract from the final image quality.
- 6.3.3 Scalpel. A scalpel is needed to cut out a portion of the filter to be examined. A number-ten curved blade scalpel is recommended.
- 6.3.4 Tweezers. A pair of fine-tipped tweezers is used to remove the membrane filter slice from the field monitor and place it upon the slide.
- 6.3.5 Lens Tissue. To insure cleanliness, a lint-free tissue is recommended. This tissue should also be used for wiping mounting tools and for cleaning slides and cover slips.
- 6.3.6 Glass Rod. A fire-polished glass rod may be used to spread the mounting solution on the slide.

- 6.3.7 Wheaton Balsam Bottle. This special glass container has a glass top which prevents contamination of the mounting solution. A glass rod is included for dispensing the solution.

7. Reagents

Chemicals should be reagent grade, free from particles and color, conforming to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

7.1 Dimethyl phthalate

7.2 Diethyl oxalate

Avoid getting the mounting solution on the skin. Wash skin promptly with soap and water if skin contact occurs.

8. Procedure

8.1 Sampling

8.1.1 General Information

Guidelines for the monitoring of employee exposures to industrial atmospheres are given in Reference 11.8. The Federal requirements for monitoring employee exposure to airborne asbestos are found in 29 CFR 1910.1001.

8.1.2 Mounting the Sampling Pump on the Worker

Fasten the sampling pump to the worker's belt and fasten the field monitor to the lapel or shirt front (as close to the breathing zone as is practical). Remove the top cover of the plastic monitor, then invert the monitor making certain the exposed filter is facing downward. Turn the pump on and adjust to the calibrated flow rate (1.0 to 2.5 lpm). Record the following information in a logbook.

1. Filter number
 2. Pump start time and date
 3. Flow rate
 4. Subject's name and job title
 5. Type of operation or process
 6. Ventilation controls and is the worker wearing a respirator approved for asbestos?
- The pump should be checked periodically during the sampling period for proper operation and flow rate.

8.1.3 Optimum Sampling Times

The requirement for the minimum count of 100 fibers or 20 fields in 8.3.9 was determined to be the best compromise to achieve adequate precision for the airborne fiber estimate and reasonable counting times. An optimum fiber density of about 1 to 5 fibers per microscope count field is recommended. To estimate appropriate sampling times for feasible counting and optimal counting, one must consider the following constraints:

1. microscope count field area (generally 0.003 to 0.006 mm²)
2. pump flow rate (typically 2.5 lpm maximum)
3. average airborne fiber concentrations
4. counting rule range of 20 to 100 fields
5. adequate fiber density to obtain a minimum count of 10 fibers in 100 fields, which is the least total fiber count that yields an acceptable count precision
6. background airborne particulate levels that can reduce the count precision due to an obscuring of fibers on the filter surface

The preceding constraints were considered in drawing Figures 1 and 2. These figures were developed from the following relationship:

$$\text{sampling time} = \frac{(\text{FB/FL}) (\text{ECA/MFA})}{(\text{FR}) (\text{AC}) (1000)} \text{ minutes}$$

where:

FB/FL = 1 to 5 fibers/field

ECA = effective collecting area of filters (855 mm² for 37-mm filter with effective diameter of 33 mm)

MFA = microscope field area (generally 0.003 to 0.006 mm²)

FR = Pump flow rate (generally 1.0 to 2.5 lpm)

AC = Air concentration of fibers in fibers/cm³.

Figure 1 (microscope field area = 0.003 mm²) and Figure 2 (microscope field area = 0.006 mm²) show optimum and feasible sampling times for a pump flow rate of 1.7 lpm. Each individual responsible for sampling asbestos should prepare a similar chart for his particular pump flow rate and microscope field area before sampling is performed to aid in estimating proper sampling times. On Figures 1 and 2, the areas with solid shading lines are generally the optimum conditions for counting. The broken shading lines are for conditions very close to optimal.

However, feasible counting conditions may extend down to about 0.1 fiber/field and and above 5 fibers/field. Recommended sampling times are most strongly influenced by background airborne particulate levels, once all the other constraints have been estimated. For heavy particulate levels, it may be necessary to limit each filter to about 60 to 180 minutes sampling duration. Each individual responsible for sampling should work closely with the microscopist to attain as high as possible filter surface fiber densities (up to about 5 fibers/field), while avoiding filter surface background particulate levels that create very difficult or impossible counting conditions. If one has very little idea of airborne fiber and particulate levels, the best procedure is to take several long samples (as one 8-hour or two consecutive 4-hour samples) in conjunction with several short samples (as four consecutive 2-hour or eight consecutive 1-hour samples). If the longer samples prove very difficult to count, the microscopist will have the shorter samples to fall back on.

From Figures 1 and 2, it can be seen that there are certain sampling times which will yield optimum fiber densities on the filter for almost all airborne fiber concentrations from 1 to 10 fibers/cm³. These optimum times have been calculated and are presented in Figure 4. Note that the optimum times given by Figure 4 are approximate and can be varied by as much as $\pm 25\%$. The nomogram is intended as a guide to be used where no prior knowledge of the air concentration is available.

8.1.4 End of Sampling Period

Remove the field monitor, replace the plastic top cover and the small end caps, and store the monitor. Always shut off the pump when changing monitors to avoid contaminating or damaging the pump. Record the pump shutoff time and flow rate in the logbook.

8.1.5 Blanks

With each batch (25 to 50 filters) of samples sent for analysis, submit two unopened field monitors which have been subjected to the same treatment as the samples except that they were not exposed to the sampling environment. Label these as blanks. If the blanks yield fiber counts greater than 5 fibers/100 fields, then the entire sampling procedure should be examined carefully for the cause of contamination. The

mounting solution of Section 8.2.1 should also be examined for contamination and/or crystal growth.

8.1.6 Shipping

The field monitors in which the samples are collected should be shipped in a rigid container with sufficient packing material to prevent crushing.

8.1.7 Numbers of Samples

When sampling for the Federal ceiling standard of 10 fibers ($>5\mu\text{m}$)/ cm^3 , [29 CFR 1910.1001(b) (3), effective July 7, 1972], only one sample (15 minutes maximum duration) is necessary, theoretically. However, several samples should be taken during expected periods of peak air concentrations to allow for detection of gross sampling or counting errors.

When sampling for determination of noncompliance with the Federal 8-hour TWA standard of 2 fibers ($>5\mu\text{m}$)/ cm^3 , [29 CFR 1910.1001(b) (2)], one should continuously sample as large a portion of the work day as is feasible for airborne concentrations of about 2 to 10 fibers/ cm^3 . However, for a lower airborne concentration such as 0.5 fiber/ cm^3 , one sample might require 4 to 8 hours sampling time in order to get the proper filter fiber density (Section 8.1.3). For this situation, the 8-hour TWA exposure would be determined from one 8-hour or two 4-hour samples as appropriate.

8.2 Sample Preparation

8.2.1 Preparation of Mounting Solution

A very important part of the sample evaluation is the mounting process. This process involves a special mounting medium of prescribed viscosity. The proper viscosity is important in order to expedite filter dissolving and still minimize particle migration. After the sample has been mounted, an elapsed time of approximately sixty minutes is needed before the sample is ready for evaluation.

Combine the dimethyl phthalate and diethyl oxalate in a one to one ratio by volume and pour into a Wheaton balsam bottle. Add approximately $0.05 (\pm 0.005)$ grams of new membrane filter per milliliter of solution to reach the necessary viscosity. The mixture must be stirred periodically until the filters have dissolved and a homogeneous mixture is formed. The normal shelf life of the mounting solution is about three months. Twenty milliliters of mounting solution will prepare approximately 300 samples.

8.2.2 Sample Mounting

Cleanliness is important! A dirty working area may result in sample contamination and erroneous counts. The following steps should be followed when mounting a sample.

1. Clean the slides and cover slips with lens tissue. Lay each slide down on a clean surface with the frosted end up. It is a good practice to rest one edge of the cover slip on the slide and the other edge on the working surface. By doing this, you keep the bottom surface (the one which contacts the filter) from becoming contaminated.
2. Wipe all the mounting tools clean with lens tissue and place them on a clean surface (such as lens tissue). All tools should be wiped clean prior to mounting each sample.
3. Using the glass rod supplied with the Wheaton balsam bottle, apply a drop of mounting solution onto the center of the slide. It may be necessary to adjust the quantity of solution so that after the cover slip has been placed on top, the solution extends only slightly beyond the filter boundary. If the quantity is greater than this, particle migration may occur.

4. Using another glass rod, spread the mounting media into a triangular shape. The size of this triangle should coincide with the dimension of the filter wedge.
5. Separate the middle and bottom sections of the field monitor case to expose the filter. Cut a triangular wedge from the center to the edge of the filter using the scalpel. The size of the wedge should approximate one-eighth of the filter surface. The filter can be very carefully removed from the cassette for cutting, but this should only be done with great care.
6. Grasp the filter wedge with the tweezers on the perimeter of the filter which was clamped between the monitor case sections. Do not touch the filter with your fingers. Place the wedge, sample side up, upon the mounting medium.
7. Pick up a clean cover slip with tweezers and carefully place it on the filter wedge. Once this contact has been made, **do not reposition the cover slip.**
8. Label the slide with the sample number and current date before proceeding to the next filter. On the bottom (backside) of the slide, trace the perimeter of the filter wedge with a felt tip marking pen. This will enable the counter, after the filter has become transparent, to stay within the filter perimeter when counting.
9. The sample should become transparent within fifteen minutes. If the filter appears cloudy, it may be necessary to press very lightly on the cover slip. This is rarely necessary; however, counting should not be started until an hour after the mounting. This allows the microscopic texture of the filter to become invisible to microscope viewing.
10. Discard the sample mount after two days if it has not been counted. Crystals appearing similar to asbestos fibers may begin to grow at the mounting media/air interfaces. They seldom present any problems if the slide is examined before two days. In any case, stay away from the filter's edges when counting and sizing.

8.3 Counting of Fibers

- 8.3.1 Place the slide on the mechanical stage of the microscope and position the center of the wedge under the objective lens and focus upon the sample. Start counting from one end of the wedge and progress along a radial line to the other end (count in either direction from perimeter to wedge tip). Random fields are selected, without looking into the eyepieces, by slightly advancing the slide in one direction with the mechanical stage control.
- 8.3.2 It is essential to continually scan over a range of focal planes (generally the upper 10 to 15 micrometers of the filter surface) with the fine focus control during each field count. This is especially necessary for asbestos fibers due to their impaction into the filter matrix.
- 8.3.3 On most airborne samples, asbestos fibers will generally have fiber diameters less than one micrometer. Therefore, it is necessary to look carefully for faint fiber images.
- 8.3.4 Regularly check phase ring alignment.
- 8.3.5 When an agglomerate (mass of material) covers a significant portion of the field of view (approx 1/6 or greater) reject the field and select another. (Do not include it in the number of fields counted.) However, report the fact as it may have meaning on other data collection.
- 8.3.6 Bundles of fibers are counted as one fiber unless both ends of the fiber can be clearly resolved.
- 8.3.7 Count only fibers with a length to width ratio greater than or equal to 3:1.
- 8.3.8 Count only fibers greater than 5 micrometers in length. (Be as accurate as possible in accepting fibers near this length.) Measure curved fibers along the curve to estimate the total length.

- 8.3.9 Count as many fields as necessary to yield a total count of at least 100 fibers. Exceptions: a) count at least 20 fields even if you count more than 100 fibers, and b) stop at 100 fields even if you haven't reached 100 fibers.
- 8.3.10 For fibers that cross either one or two sides of the counting field, the following procedure is used to obtain a representative count.
COUNT any fiber greater than 5 micrometers in length, that lies entirely within the counting area. COUNT as "½ fiber" any fiber with only one end lying within the counting area. DO NOT COUNT any fiber crossing any two sides.
Reject and do not count all other fibers. Refer to Figures 5 through 10. Note that the fibers in Figures 5 through 10 are not representative of the appearance of most asbestos fibers. Most fibers have a very faint image.

9. Calibration and Standards

9.1 Sampling Train Calibration

The accurate calibration of the sampling pump is essential to the correct calculation of the air volume sampled. The frequency of calibration is dependent on the use, care, and handling to which the pump is subjected. Pumps must be recalibrated if they have just been repaired, misused, or received from the manufacturer. If the pump receives hard usage, more frequent calibration may be necessary. Ordinarily, pumps should be calibrated in the laboratory both before they are used in the field and after they have been used to collect a large number of field samples.

The accuracy of calibration is dependent upon the type of instrument used as a reference. The choice of a calibration instrument will depend largely on where the calibration is performed. For laboratory testing, a 1-liter buret used as a soap bubble flow meter or wet-test meter is recommended. Other standard calibrating instruments, such as a spirometer, Mariott's bottle, or dry gas meter can be used. The calibration should be of sufficient precision that the 95% confidence limits on the flow rate are $\pm 10\%$ (95% of the flow rates will fall within $\pm 10\%$ of the calibrated value).

Instructions for calibration with the soap bubble flow meter follow. The sampling train used (pump, hose, filter cassette) in the pump calibration should be the same as the one used in the field.

- 9.1.1 Check the voltage of the pump battery with a voltmeter both with the pump off and while it is operating to assure adequate voltage for calibration. If necessary, charge the battery to manufacturer's specifications.
- 9.1.2 Fill a beaker with 10 ml of soap solution.
- 9.1.3 Connect the filter cassette inlet to the top of the buret with a length of hose.
- 9.1.4 Turn the pump on and moisten the inside of the soap bubble meter by immersing the open end of the buret into the soap solution and drawing bubbles up the inside of the buret. Perform this task until the bubbles are able to travel the entire length of the buret without breaking.
- 9.1.5 Adjust the pump rotameter to provide a flow between 1.5 to 2.5 lpm.
- 9.1.6 With a water manometer, check that the pressure drop across the filter is less than 13 inches of water (about 1 inch of mercury).
- 9.1.7 Start a soap bubble up the buret and measure the time it takes for the bubble to travel a minimum volume of 1 liter.
- 9.1.8 Repeat the procedure in 9.1.7 at least three times, average the results, and calculate the calibrated flow rate by dividing the volume traveled by the soap bubble by the elapsed time. If the range between the highest and lowest of the three flow rates is greater than about 0.33 lpm, then the calibration should be repeated since it is likely that the precision is not adequate.

9.1.9 Data required for the calibration include the volume measured, elapsed time, pressure drop, air temperature, atmospheric pressure (or elevation), pump serial number, date, and name of person performing the calibration.

9.1.10 Corrections to the flow rate for pumps with rotameters may be necessary if the pressure (elevation) or temperature where the samples are collected (actual flow rate) differs significantly from that where the calibration was performed (indicated flow rate). Actual flow rates at time of sampling may be calculated for a linear scale rotameter by using the following correction formula:

$$Q_{\text{actual}} = Q_{\text{indicated}} \sqrt{\frac{P_{\text{cal}}}{P_{\text{actual}}} \cdot \frac{T_{\text{actual}}}{T_{\text{cal}}}}$$

where both pressure (P) and temperature (T) are in absolute units such as:

psia = psig + 14.7

deg Rankin = deg Fahrenheit + 460

deg Kelvin = deg Celsius + 273

9.2 Microscope Setup

9.2.1 Porton Reticle and the Counting Field

The asbestos fiber count procedure consists of comparing fiber length to the diameters of calibrated circles of a Porton reticle, and counting all fibers greater than 5 micrometers in length lying within a given counting field area. The Porton reticle is a glass plate inscribed with a series of circles and rectangles. The left half of the reticle is divided into six rectangles constituting the counting field. The counting field is illustrated in Figures 5 through 10.

9.2.2 Placement in Eyepiece

The Porton reticle is placed inside the Huygenian eyepiece where it rests on the field-limiting diaphragm. If other types of eyepieces are used, it may be necessary to insert a counting collar for retaining the reticle. The reticle should always be kept clean, since dirt on the reticle is in focus and could complicate the counting and sizing process.

9.2.3 Stage Micrometer

The Porton reticle cannot be used for counting until it has been properly calibrated with a stage micrometer. Most stage micrometer scales are approximately two millimeters long and are divided into units of one-hundredth of a millimeter (ten micrometers).

9.2.4 Microscope Adjustment

When adjusting the microscope, follow the manufacturer's instructions while observing the following guidelines.

1. The light source image must be in focus and centered on the condenser iris or annular diaphragm.
2. The particulate material to be examined must be in focus.
3. The illuminator field iris must be in focus, centered on the sample, and opened only to the point where the field of view is illuminated.
4. The phase rings (annular diaphragm and phase-shifting elements) must be concentric.

9.2.5 Porton Reticle Calibration Procedure

Each eyepiece-objective-reticle combination on the microscope must be calibrated. Should any of the three be changed (disassembly, replacement, zoom adjustment, etc.), the combination must be recalibrated. Calibration may change if interpupillary dis-

tance is changed. For proper calibration, the following procedure should be followed closely.

With a 10X objective in place, place the stage micrometer on the mechanical stage, focus the millimeter scale, and center the image. Change to the 40-45X objective and adjust the first millimeter scale division to coincide with the left boundary of the Porton rectangle. Measure the distance between the left and extreme right boundaries of the Porton rectangle, estimating any portion of the final division. This measurement represents 200 L units. The rectangle is 100 L units on the short vertical dimension. The calculated "L" is inserted into the formula $D = L(2^N)^{1/2}$ where "N" is the circle number (indicated on the reticle) and "D" is the circle diameter. Since the circle diameters vary logarithmically, every other circle doubles in diameter. For example, circle number three is twice the diameter of number one; number four is twice the diameter of number two. When the circle sizes have been determined, the counting field area which consists of the left six smaller rectangles can be calculated from the relation $10,000 L^2$. This completes the reticle calibration for this specific objective-eyepiece-reticle combination.

Example for Porton Reticle

The following calibration was obtained for a pair of 10X Huygenian eyepieces and a 43X objective:

$$200 L = 0.148 \text{ mm} = 148 \text{ micrometers}$$

$$100 L = 0.074 \text{ mm} = 74 \text{ micrometers}$$

$$\text{One L-unit} = 0.74 \text{ micrometers}$$

Thus Circle #1 has a diameter $D = L(2^N)^{1/2} = 0.74(2^1)^{1/2} = 0.74 (1.414) = 1.05$ micrometers.

Then our circle diameter calibration table looks like:

$$\text{Diameter of Circle \#1} = 1.05 \text{ micrometers}$$

$$\#2 = 1.48$$

$$\#3 = 2.09$$

$$\#4 = 2.96$$

$$\#5 = 4.19$$

$$\#6 = 5.92$$

$$\text{Field area} = (10,000) (L^2) = (100 L) (100 L) = (0.074) (0.074) = 0.0055 \text{ mm}^2$$

Thus fibers with a length greater than a distance halfway between the diameters of the #5 and #6 circles would be counted.

If a Patterson Globe and Circle reticle is used, a different calculation procedure is required. The circle diameters are related as follows. The #25 circle diameter is (0.1) (reticle length).

The circle diameters are proportional to the ratio of their numbers. Thus the #20 circle diameter is (20/25) or 0.8 times the #25 circle diameter.

10. Calculations

- 10.1 The average airborne asbestos fiber concentration estimated by the filter sample may be calculated from the following formula:

$$AC = \frac{[(FB FL) - (BFB BFL)] (ECA)}{(1000) (FR) (T) (MFA)}$$

where:

- AC = Airborne fiber concentration in (fibers > 5 μ m)/cm³.
BFB = Total number of fibers counted in the BFL fields of the blank or control filters in fibers > 5 μ m.
BFL = Total number of fields counted on the blank or control filters.
ECA = Effective collecting area of filter (855 mm² for a 37-mm filter with effective diameter of 33 mm).
FR = Pump flow rate in liters/min (lpm).
FB = Total number of fibers counted in the FL fields in fibers > 5 μ m.
FL = Total number of fields counted on the filter.
MFA = Microscope count field area in mm² (generally 0.003 to 0.006).
T = Sample collection time in minutes.

- 10.2 Recount criteria. It is very desirable for a counter to conduct a "blind recount" for about 1 in every 10 filter wedges (slides) counted. Alternatively, a second counter could perform the blind recount. In training sessions for novice counters, the trainee should conduct a blind recount for filter wedges counted by an experienced, proficient counter. In all cases, we will observe differences between the first and second counts of the same filter wedge. Most of these differences will be due to chance alone, that is, due to the random variability (precision) of the count method. Statistical recount criteria enable us to decide whether observed differences can reasonably be explained due to chance alone or are probably due to systematic differences between counters or microscopes or due to some other biasing factor. The following recount criterion is for a pair of counts that estimate some airborne fiber concentration (AC) in fibers/cm³. The criterion is given at the type-I error level. That is, there is a 5% maximum risk that we will reject a pair of counts for the reason that one might be biased, when the large observed difference is really due to chance. Reject a pair of counts because one might be biased if:

$$(AC_2 - AC_1) \text{ exceeds } 2.77(\overline{AC})(CV_{FB})$$

where:

- AC₁ = lower estimated airborne fiber concentration
AC₂ = higher estimated airborne fiber concentration
 \overline{AC} = average of the two airborne concentration estimates
CV_{FB} = average CV for the two concentration estimates which are a function of the total fiber count (FB) in each case. Use the relation in Section 4 or Figure 3.

For a pair of counts on the same filter, reject the pair because one might be biased if:

$$(FB_2 - FB_1) \text{ exceeds } 2.77(\overline{FB})(CV_{FB})$$

where:

- FB₁ = lower fiber count on the filter (total fibers)
FB₂ = higher fiber count on the filter (total fibers)
 \overline{FB} = average of the two total fiber counts
CV_{FB} = CV_T for the value FB. Use the relation in Section 4 or Figure 3.

11. References

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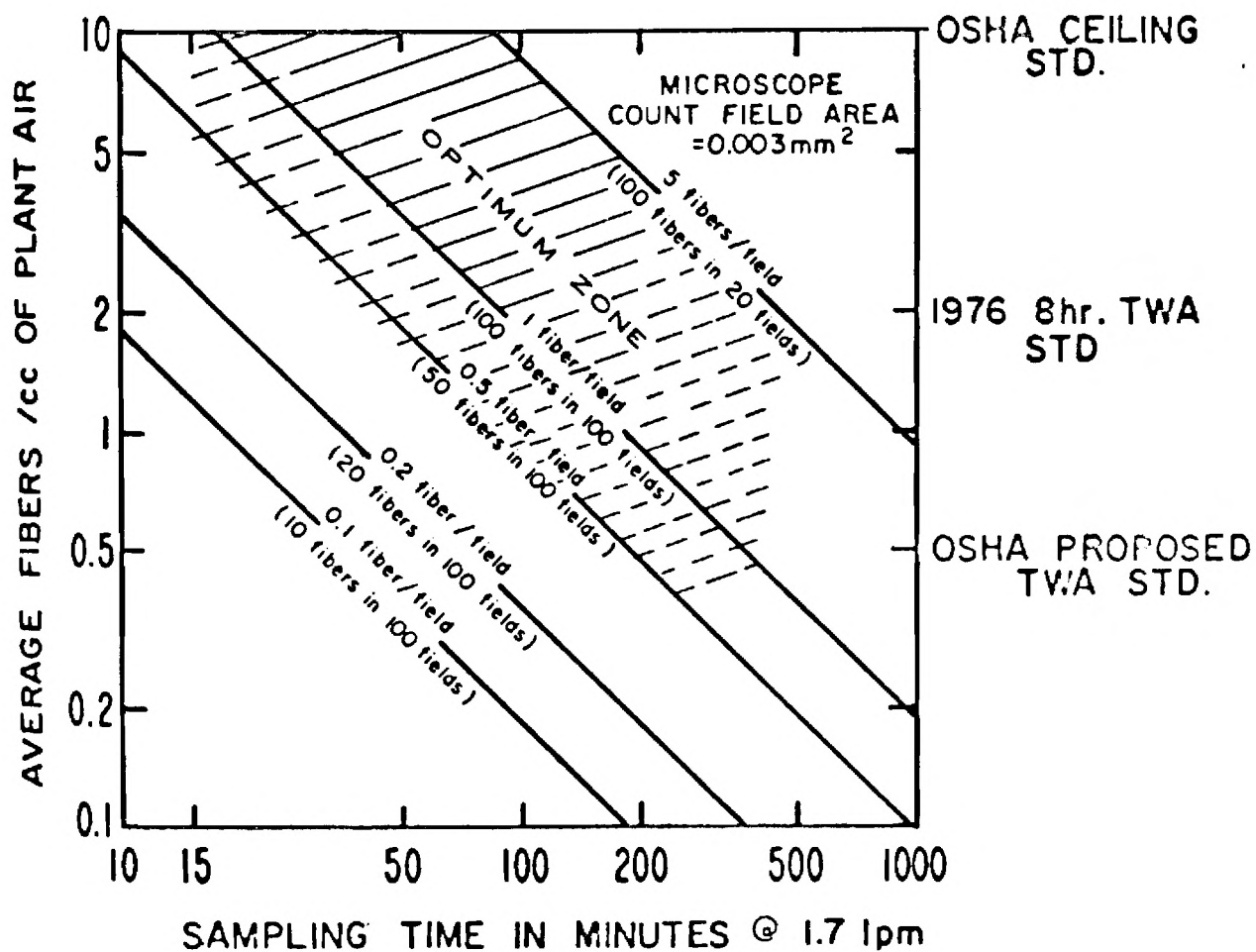


FIGURE 1. Optimum Sampling Times for airborne asbestos where microscopic field area = 0.003 mm²

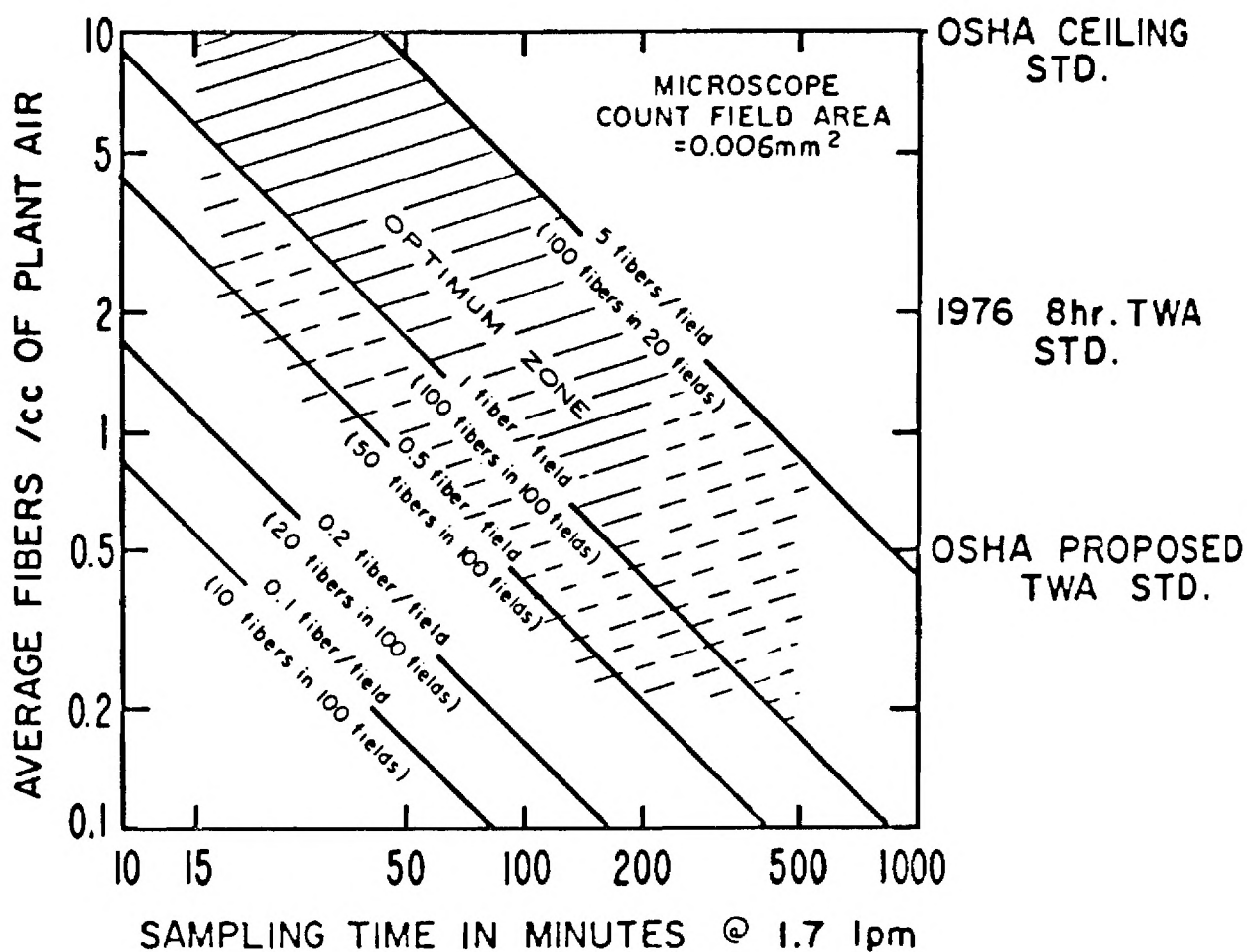


FIGURE 2. Optimum sampling times for airborne asbestos where microscopic field area = 0.006 mm²

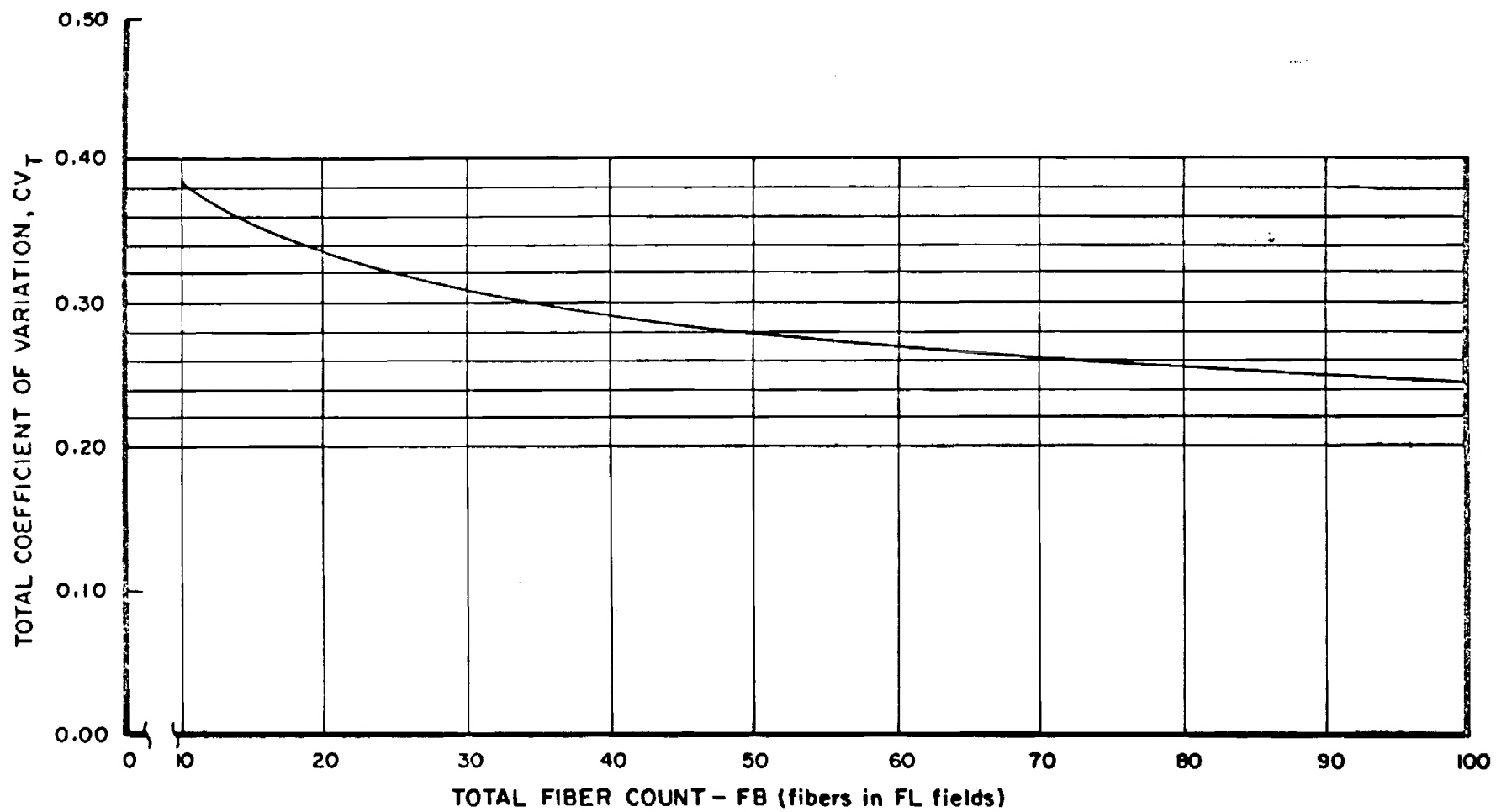


FIGURE 3. Total coefficient of variation as a function of total fiber count

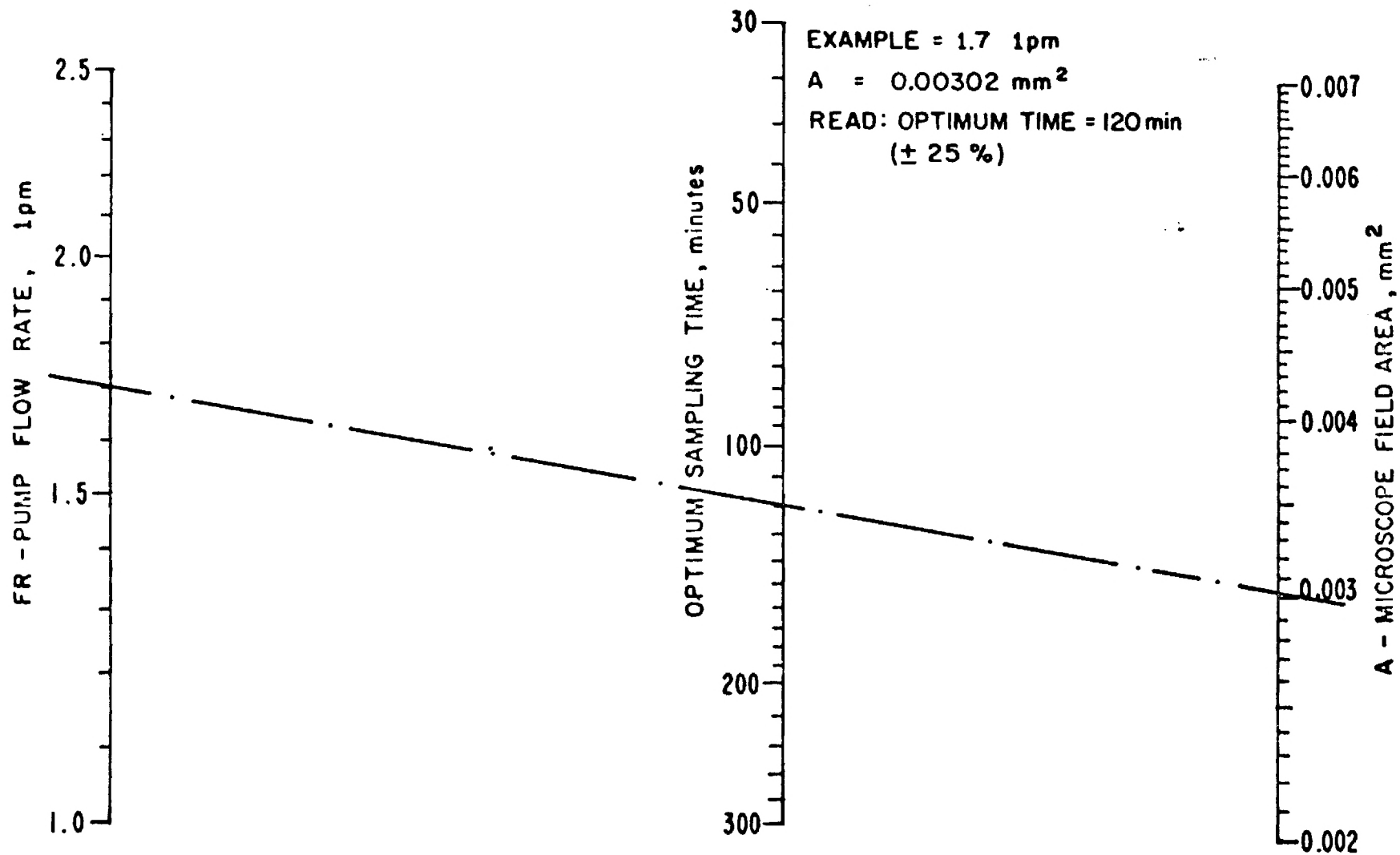


FIGURE 4. Nomogram of optimum sampling times for airborne asbestos fibers in concentrations of 1 to 10 fibers/cm³

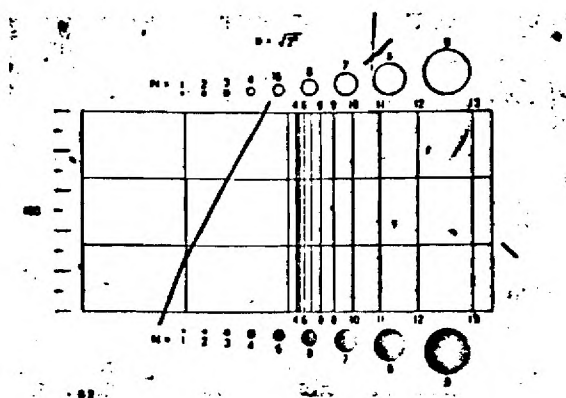


FIGURE 5

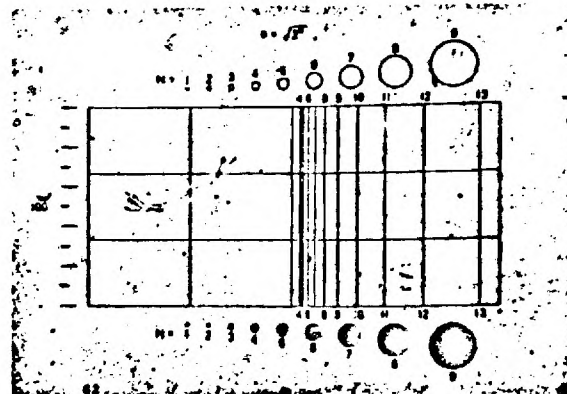


FIGURE 6

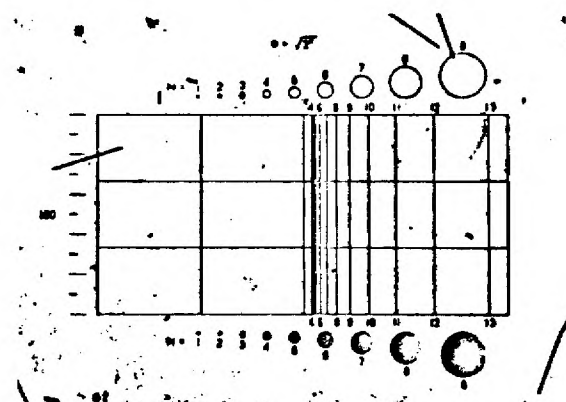


FIGURE 7

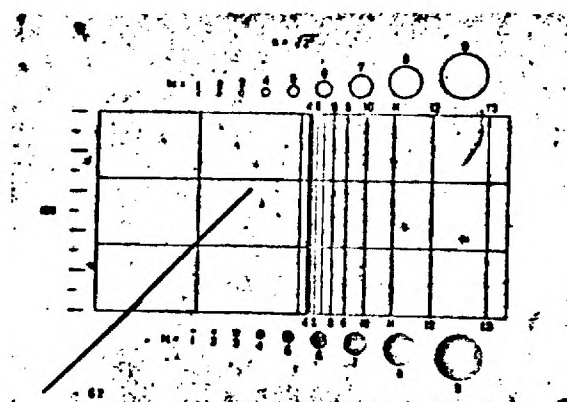


FIGURE 8

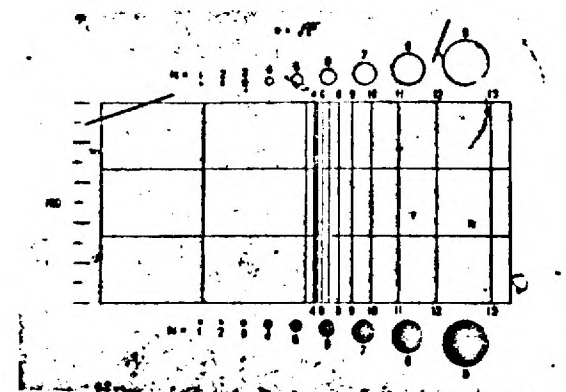


FIGURE 9

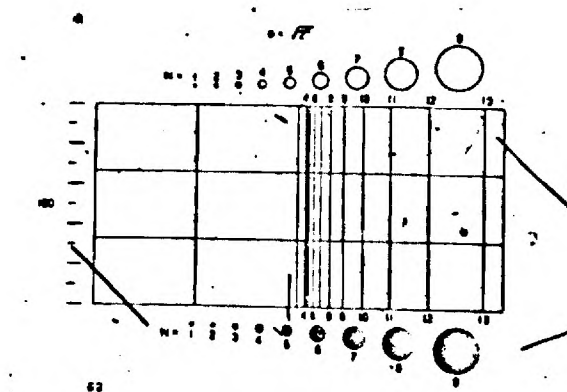


FIGURE 10

LIST OF FIGURES

(5 through 10)

FIGURE 5. DO NOT COUNT. Fiber crosses top and bottom sides.

FIGURE 6. COUNT. One fiber.

FIGURE 7. COUNT. One-half fiber. Fiber crosses left side and one end lies within count area.

FIGURE 8. COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.

FIGURE 9. DO NOT COUNT. Fiber crosses two sides.

FIGURE 10. DO NOT COUNT. Fiber crosses two sides (bottom left corner).

COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.

COUNT. One fiber (top right corner).